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(54) Title of the Invention: High Density Light Waveguide and Method for Manufacturing Same

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SPECIFICATION

1. Title of the Invention

High Density Light Waveguide and Method for Manufacturing Same

2. Claims

(1) A high density light waveguide comprising two light waveguide plates (each) having a plurality of linear light waveguides that are composed of a cured photosensitive resin with a higher refractive index than that of the surface of a substrate and that are formed in rows with spaces between them on the surface of said substrate, characterized in that (1) said light waveguide plates are joined together over the entire surface of these light waveguide plates with the light waveguides facing inward, and (2) the state of this joining is such that the core rows constituting the linear light waveguides of the two light waveguide plates mutually fit into the spaces of the other light waveguide plate with a small gap in between, and the core rows of the two light waveguide plates that are fitted together are entirely isolated by a clad layer that fills in this small gap and is composed of a resin having a refractive index lower than the refractive index of the light waveguides.

(2) A method for manufacturing a high density light waveguide, characterized in that a layer composed of photosensitive resin composition with a higher refractive index than that of the surface of a substrate is formed on the substrate, after which this layer is exposed and cured in a pattern and the

unexposed portion is then removed to obtain a first light waveguide plate having core rows composed of linear light waveguides arranged with spaces in between them, and the entire surface of the light waveguide side of said first light waveguide plate is then coated with a liquid resin for forming a clad layer with a lower refractive index than that of said photosensitive resin composition, after which the region coated with said resin is superposed with the corresponding part of a second light waveguide plate produced by the same method as the first light waveguide plate such that the core rows (the linear light waveguides) of the two light waveguide plates mutually fit into the spaces of the other light waveguide plate with a small gap in between, and said liquid resin is cured to form a clad layer.

3. Detailed Description of the Invention

Field of Industrial Utilization

The present invention relates to a light waveguide for transmitting optical information by means of LED light, laser light, or the like, and more particularly a high density light waveguide composed of a polymer, and to a method for manufacturing the same.

Prior Art

Some of the apparatuses that make use of optical technology at the present time are designed such that they transmit LED light or laser light through rows of light waveguides, examples of which include printers, character or bar code readers, and position

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sensors.

The light waveguide rows used here might be an optical fiber array in which the optical fibers are uniformly aligned, but productivity is not always high in this case, and it is exceedingly difficult to manufacture anything but straight, parallel light waveguide rows.

A light waveguide sheet is one possibility for providing light waveguide rows of various shapes. This can be produced, for example, by a method in which a core material is injected into a metal mold and transferred to a clad sheet, or a forming method in which a plastic sheet is embossed and then subjected to a treatment for lowering the refractive index of the surface. A photopolymerization method in which a photopolymerizable material is exposed through a photomask has also been developed, and there have been proposals for the formation of a light waveguide composed of a photosensitive resin with a high refractive index on a substrate of plastic, glass, or the like.

Problems Which the Invention is Intended to Solve

When a light waveguide is used to transmit optical information, there is a need for a higher density light waveguide so that more information can be transmitted. With the above-mentioned formation methods, however, a density of a few light waveguides per millimeter was the limit.

With photopolymerization, on the other hand, it is possible to form light waveguides in a higher density. The minimum width and spacing of the light waveguides that can be attained with photopolymerization is generally held to be about the same as the thickness of the photosensitive layer. For instance, if the thickness of the photosensitive layer is 50 μ m, then a light waveguide with a width of 50 μ m can be formed at a spacing of 50 μ m, so the light waveguides can be formed at a density of ten rows per millimeter.

Means Used to Solve the Above-Mentioned Problems

As a result of investigation into the above situation, the inventors discovered the high density light waveguide given below.

Specifically, the present invention relates to:

(1) a high density light waveguide comprising two light waveguide plates [each] having a plurality of linear light waveguides that are composed of a cured photosensitive resin with a higher refractive index than that of the surface of a substrate and that are formed in rows with spaces between them on the surface of said substrate, characterized in that (1) said light waveguide plates are joined together over the entire surface of these light waveguide plates with the light waveguides facing inward, and (2) the state of this joining is such that the core rows constituting the linear light waveguides of the two light waveguide plates mutually

fit into the spaces of the other light waveguide plate with a small gap in between, and the core rows of the two light waveguide plates that are fitted together are entirely isolated by a clad layer that fills in this small gap and is composed of a resin having a refractive index lower than the refractive index of the light waveguides; and

(2) a method for manufacturing a high density light waveguide, characterized in that a layer composed of photosensitive resin composition with a higher refractive index than that of the surface of a substrate is formed on the substrate, after which this layer is exposed and cured in a pattern and the unexposed portion is then removed to obtain a first light waveguide plate having core rows composed of linear light waveguides arranged with spaces in between them, and the entire surface of the light waveguide side of said first light waveguide plate is then coated with a liquid resin for forming a clad layer with a lower refractive index than that of said photosensitive resin composition, after which the region coated with said resin is superposed with the corresponding part of a second light waveguide plate produced by the same method as the first light waveguide plate such that the core rows (the linear light waveguides) of the two light waveguide plates mutually fit into the spaces of the other light waveguide plate with a small gap in between, and said liquid resin is cured to form a clad layer.

The present invention will now be described in detail through reference to the figures.

Figure 1 illustrates an example of a cross section of one of the light waveguide plates that are superposed and joined together in the present invention. In the figure, 1 is a substrate, 2 is a core row (a linear light waveguide), and 3 is a light waveguide space produced by developing and removal [of the resin]. The first and second light waveguide plates are both the same, with substantially no difference between them. Figure 2 is a cross section illustrating the state when the core row surfaces have been coated with a liquid resin 4 that is used for forming a clad layer. Figure 3 is a cross section illustrating the superposed and joined portion of the two light waveguide plates. Each of the core rows 2 is thoroughly isolated [from the other rows] by the clad layer 4, and it can be seen that the density of the core rows has been doubled. Also, as shown in Figure 4, the core rows need not be parallel and straight, and may instead have a converging shape, and as long as each single row is entirely isolated by the clad layer, the core rows may also be curved.

The manufacturing method of the present invention will now

be described.

There are no restrictions on the material of the substrate, but examples include polyethylene terephthalate, polyvinyl chloride, polyethylene, polyacrylonitrile, polyvinyl alcohol, polymethyl methacrylate, polyoxymethylene, polypropylene, polymethyl pentene, silicone resin, polyvinylidene fluoride, polytetrafluoroethylene, and other such macromolecular materials; soda glass, Pyrex glass, vycor glass, quartz glass, and other such glass materials; and silicon, ADP, KDP, and other such monocristalline materials. It is preferable for the surface to be as smooth as possible.

If the refractive index of the photosensitive resin that coats this surface is higher than that of the substrate, then a material whose refractive index is lower than the refractive index of the photosensitive resin must be formed on the surface of the substrate. It is preferable to coat with a cured polyfunctional acrylate or methacrylate, methyl polymethacrylate, a fluorine-containing methacrylic acid ester, a silicone resin, a UV-setting resin, or the like.

Next, a photosensitive resin composition layer is formed over this substrate. It is preferable for the photosensitive resin composition to be a mixture of a polyfunctional monomer and a photopolymerization initiator, or this mixture with a linear polymer added to it.

Examples of polyfunctional monomers include ethylene glycol diacrylate, triethylene glycol diacrylate, tetraethylene glycol diacrylate, hexaethylene glycol diacrylate, trimethylolpropane triacrylate, pentaerythritol diacrylate, pentaerythritol triacrylate, 1,4-butanediol diacrylate, propylene glycol diacrylate, and compounds (1) to (4) given in the Specification of Japanese Patent Application 62-149797. A radical polymerization initiator is preferable as the photopolymerization initiator, examples of which include 2-ethylanthraquinone, benzoin methyl ether, diisopropyl thioxanthol, benzophenone, Michler's ketone, benzyl dimethyl ketal, and 1-phenyl-1,2-propanedione-2-*o*-(ethoxycarbonyl)oxime.

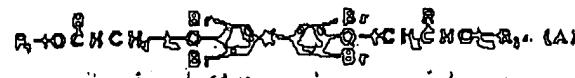
Polymethyl methacrylate, polystyrene, or the like can be used as the linear polymer. From the standpoint of optical transmissivity, preferred combinations are disclosed in Japanese Patent Application 62-149797.

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The photopolymerization initiator should be used in an amount of 0.1 to 10 wt%, and preferably 0.5 to 3 wt%, with respect to the entire composition.

The weight ratio of the polyfunctional monomer and the linear polymer should be 90:10 to 20:80, and preferably 70:30 to 30:70.

The refractive index of a polyfunctional acrylate or a polyfunctional methacrylate, which are commonly used as polyfunctional monomers, is usually around 1.5, and when a substrate of glass or polymethyl methacrylate is used, the surface of these substrates must be coated with a fluorine polymer, a silicone polymer, or the like. A photosensitive resin composition with a high refractive index must be used when a substrate of glass or polymethyl methacrylate or of a macromolecular material such as diethylene glycol bisallyl carbonate is directly coated with the core material, and a composition whose principal components are a bromide expressed by the following General Formula A



(where X is CH_3 , $\text{C}(\text{CH}_3)_2$, $\text{CH}=\text{CH}_2$, O, or SO_2 ; R is CH_3 or H; R₁ is $\text{COCH}=\text{CH}_2$, $\text{COC}(\text{CH}_3)=\text{CH}_2$, or H; R₂ is $\text{COCH}=\text{CH}_2$, or $\text{COC}(\text{CH}_3)=\text{CH}_2$; and n and m are integers from 0 to 4)

and a polystyrene-based compound including repeating units expressed by the following General Formula B

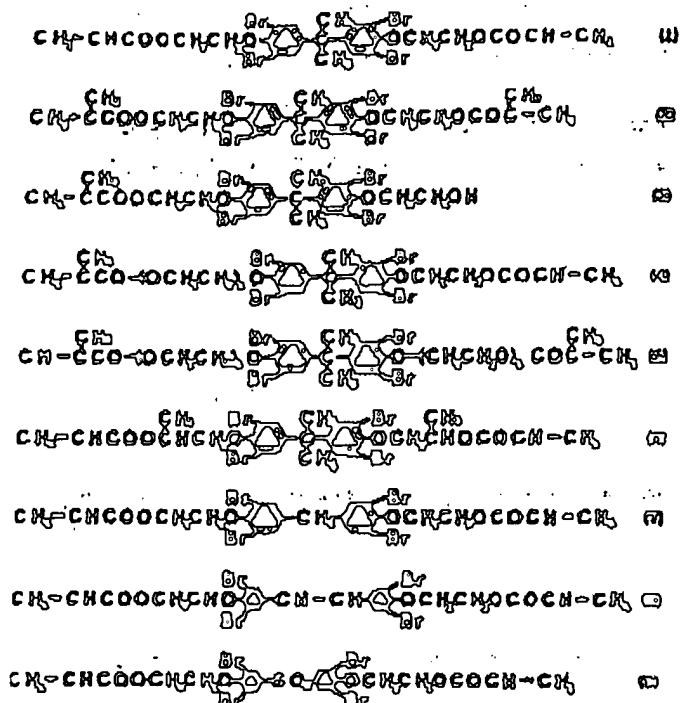


(where Y is H, CH_3 , $\text{CH}=\text{CH}_2$, OCH_3 , or Cl)

is recommended as a material that is favorable for this purpose.

Specific examples of the bromides expressed by General

Formula A are the compounds expressed by the following Structural Formulas 1 to 9, with the compounds expressed by Structural Formulas 1 and 2 being preferable.



In this case, polystyrene itself is preferable as the polystyrene-based compound.

It is also possible to subject the surface of the support to a treatment for such purposes as enhancing its adhesion to the organic light waveguide in question. Examples of such treatments include a corona discharge treatment of the above-mentioned macromolecular materials, and a silane coupling treatment of the above-mentioned glass materials.

There are no restrictions on the thickness of the layer that forms the photosensitive resin composition, but a range of 10 to 200 μm is preferable, with 20 to 100 μm being even better.

The photosensitive resin composition layer is generally obtained by coating the substrate with a solution of this composition by spin coating, dip coating, roll coating, bar coating, or another such method, and then drying this coating.

Examples of exposure methods include ultraviolet irradiation using an extra-high pressure mercury vapor lamp via a photomask, and a scanning method using an electron beam or a powerful

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visible light beam. During exposure, it is possible to employ a method that involves conducting the exposure in an inert atmosphere or pressing a sheet with a low oxygen permeability against the composition for the purpose of reducing the amount of oxygen which would otherwise hinder the polymerization of the composition in the exposed portion.

The removal of the unexposed portion, or in other words, developing, is generally accomplished by using a solvent (developing liquid) to dissolve away the photosensitive resin composition by dipping, spraying, or another such method, with spraying being particularly favorable.

There are no particular restrictions on the above-mentioned developing liquid as long as the solubility of the polymer of the composition in the exposed portion is lower than the solubility of the composition in the unexposed portion. Also, the ideal developing liquid will depend on the composition being used, but an organic developing liquid is generally preferred for the purposes of the present invention. Examples of favorable developing liquids include methyl ethyl ketone and toluene, but it is preferable to use non-flammable 1,1,1-trichloroethane, tetrachloroethane, or the like. When the photosensitive resin composition is used in the form of a liquid, it can also be blown away with a pressurized gas or washed away with a surfactant aqueous solution.

When the light waveguide pattern is linear, for example, the width of the light waveguide must be the same as or greater than the thickness of the photosensitive layer, and the light waveguide spacing must be at least as great as the light waveguide width.

The liquid resin that forms the clad layer may be a thermoplastic resin as long as it satisfies the adhesion requirements, but a thermosetting or photosetting resin is generally better.

Effects of the Invention

Because the light waveguides disclosed in the present invention are produced through the use of photolithography technology, light waveguides can be produced in extremely high density. For example, the light waveguide density is only a few waveguides per millimeter in the case of light waveguides obtained by the forming methods discussed above, but a density of 10 or more light waveguides per millimeter can be achieved with the method disclosed in the present invention.

The high density light waveguides disclosed in the present invention can be used in bar code readers, facsimiles, and other

reading-use light waveguides, and in light waveguides used in position sensors, optical printers, and the like.

Working Examples

Working examples will now be given, in which "parts" refers to weight parts.

Working Example 1

2 parts dimethoxyphenylacetylphenone was added as a photopolymerization initiator and thoroughly mixed with a solution comprising 70 parts of the bromide expressed by Structural Formula 2, 30 parts polystyrene, and 100 parts methyl ethyl ketone. A glass substrate that had undergone a silane coupling treatment was coated with the above solution by bar coating, after which the coating was heated and dried at 70°C, which yielded a coating film with a thickness of approximately 50 μ m. This was irradiated through a photomask by a high-pressure mercury vapor lamp, and heated for 30 minutes at 70°C, after which it was developed with trichloroethane, which formed 30 linear light waveguides with a width of 50 μ m and a length of 300 μ m in parallel at a spacing of 70 μ m.

The rows of the light waveguides obtained here were coated with a liquid obtained by adding benzyl dimethyl ketal in an amount of 2 wt% to 70PI made by Kyoci Jushi, a light waveguide film on which the same pattern had been formed was laid over this such that the light waveguide cores thereof would fit in between the previous light waveguide core rows, and these were pressed together and then irradiated with ultraviolet rays at 800 mJ/cm².

The ends of the light waveguides were polished, after which the loss factor of the light waveguides was measured using an He-Ne laser (2 mW output) with a wavelength of 632.8 nm and found to be 20 dB/m, which is a favorable value.

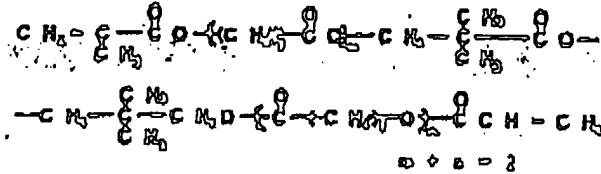
Working Example 2

A PMMA sheet with a thickness of 1 mm that had been coated with poly(2,2,2-trifluoroethyl methacrylate/glycidyl methacrylate) to a thickness of 10 μm was coated by doctor blade with a uniform solution obtained by dissolving 58 parts polymethyl methacrylate (made by Asahi Chemical Industry Co., 42 parts HD-220

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bifunctional methacrylate (made by Nihon Kayaku Co.; the compound of Structural Formula 10), and 1 part benzyl dimethyl ketal in 135 parts methyl ethyl ketone, and this coating was dried, which yielded a transparent coating film with a thickness of 40 μm . This was irradiated with 200 mJ/cm^2 of ultraviolet rays through a photomask, developed with 1,1,1-trichloroethane, and rinsed with water, which yielded two light waveguide plates with the pattern shown in Figure 4. A UV-setting silicone, TUV-6000 (made by Toshiba Silicone), was applied between the two light waveguide plates, after which they were pressed together and irradiated with 800 mJ/cm^2 of ultraviolet rays in the same manner as in Working Example 1 to obtain light waveguides. The waveguide loss of the light waveguides thus obtained was measured in the same manner as in Working Example 1 and found to be 4 dB/m.

Structural Formula 10



Working Examples 3 to 9

Light waveguides were produced by the same method as in Working Example 1 except that the mixtures given in Table 1 were used instead of the bromide (2) and polystyrene of Working Example 1, producing the photosensitive resin compositions given in Table 1. The loss factors of the light waveguides thus obtained were similarly measured, and are also given in Table 1.

Table 1

Starting Energy	Mixture composition (weight ratio)	Irradiation (mJ/cm ²)	Loss factor (dB/m)
3	bromide (1) / polystyrene (70/30)	300	20
4	bromide (3) / poly(p-chlorostyrene) (50/50)	400	80
5	bromide (4) / poly(p-methylstyrene) (60/40)	350	60
6	bromide (5) / polystyrene (60/40)	300	50
7	bromide (6) / polystyrene (60/40)	300	50
8	bromide (7) / (p-methylstyrene) (50/50)	400	90
9	bromide (8) / (p-chlorostyrene) (30/70)	500	150

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4. Brief Description of the Drawings

Figure 1 is an example of a cross section of one of the light waveguide plates that are superposed and joined together in the present invention.

Figure 2 is a cross section of a light waveguide plate and illustrates the state when the core row surfaces have been coated with a liquid resin that is used for forming a clad layer;

Figure 3 is a cross section illustrating the superposed and joined portion of the two light waveguide plates; and

Figure 4 is a surface view illustrating the pattern of core rows of the light waveguide plate produced in Working Example 2.

1 ... substrate

2 ... core

3 ... unexposed portion

4 ... clad resin layer

Applicant: Asahi Chemical Industry Co., Ltd.

Agent: Toru Hoshino, Patent Attorney

Figure 1

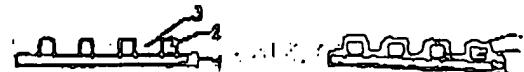


Figure 2



Figure 3

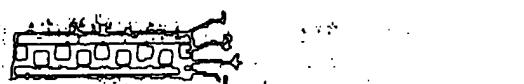


Figure 4

